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Cross Service Fixed-Wing Cost Estimation

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14. ABSTRACT
The TRADOC Analysis Center (TRAC) seeks to develop a process to compute the operational costs to meet a mission demand. TRAC conducts Analysis of Alternatives (AoA) for acquisitions projects. Besides the Army-proposed capabilities to fulfill a DOTMLPF gap, an AoA can require consideration of joint capability as well. Strick comparisons of the life cycle costs of alternative munitions/systems doesn't always provide a complete picture of the true costs of employment; this is especially true for munitions delivered from a platform operated by one of the Army's sister services. The analytic community and senior decision makers desire a method to compare the cost to conduct an attack of a given target with alternative means whether those means are delivered from an aerial platform (rotary wing, fixed wing) or surface (ship, ground launcher). For this effort we will call this cost consideration, "mission cost." This project intends to describe methodologies used by the Air Force and Navy to develop fixed wing O&S cost estimates and how they may be used to develop mission costs that are equitable for all systems considered within a study or project.

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Executive Summary

Background

The TRADOC Analysis Center (TRAC) seeks to develop a process to compute the operational costs for fixed wing aircraft to meet a mission demand in order to use those costs in the development of Analysis of Alternatives (AoA) for acquisition projects. An Analysis of Alternatives (AoA) to fulfill a Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities (DOTMLPF) gap can require consideration of joint and service capability. Strick comparisons of the life cycle costs of alternative munitions/systems does not always provide a complete picture of the true costs of employment; this is especially true for munitions delivered from a platform operated by one of the Army's sister services. The analytic community and senior decision makers desire a method to compare the cost to conduct an attack of a given target with alternative means, whether those means are delivered from an aerial platform (rotary wing, fixed-wing) or surface (ship, ground-launcher). For this effort, we will call this cost consideration "mission cost." Unfortunately, the costing methods -specifically derivation of operations and support costs (O&S) - outside of the Army can be somewhat opaque. This project was an effort to clarify the costing methods for O&S costs for fixed-wing delivery platforms with the intent of extending the research to other cross-service mission costs in the future.

Methods

The study team elicited recommendations from subject matter experts (SME) in the fixed-wing budgeting field from the Air Force and Navy and used historical data from the costing databases maintained by each service: AFTOC for the Air Force and VAMOSC for the Navy.[1][2] Using the supplied data and SME advice, the study team computed a linear regression that will allow TRAC to compute average future fixed-wing cost per flight hour estimates using data provided by the respective services. This analysis used linear regression with logarithmic transformation to estimate the increase per year of cost per flight hour for fixed-wing costs. We also calculated a confidence interval around the mean value of cost per flight hour to better estimate the expected cost of fixed wing assets.

[1] Air Force. *Air Force Total Ownership Cost (AFTOC)*. https://aftoc.hill.af.mil/.

[2] Navy. *Navy Visisitilby and Management Of Operating and Support Costs (VAMOSC)*. https://www.vamosc.navy.mil/.

Limitations

The main limitation for this project was the procurement of data. We used the Air Force and Navy historical costing databases to collect all of our data. The databases had the same information fields, with some cosmetic differences. We had to rely on the validity of this data, as we did not have access to the actual unit records.

Results

We recommend using five of the six different costing categories provided in the Operations and Support Cost-Estimation Guide.[3] The five categories that should be used are: 1.0 Unit-Level Manpower, 2.0 Unit Operations, 3.0 Maintenance, 4.0 Sustaining Support, and 5.0 Continuing System Improvements. The only category omitted from the calculations is 6.0 Indirect Support.

Logistic model analysis led us to also recommend increasing the cost per flight hour by 4.5% each year. This increase will account for aggregate cost increases from personnel, equipment, and training.

[3] Department of Defense. *Operating and Support Cost-Estimating Guide*. DoD, Mar. 2014.

Cross Service Fixed-Wing Cost Estimation
Chapter 1
Introduction

Background

The U.S. Army Training and Doctrine Command Analysis Center (TRAC) is often responsible for conducting analysis for the Army that can cross the service lines, integrating analysis of systems in the Air Force and the Navy, as well as systems in the Army. For this analysis to be accurate, TRAC needs a method to provide accurate and timely cost estimates for many of the resources in the Air Force and Navy, resources that are not organic to the Army. In addition to providing the cost estimates for these resources, it is essential that the cost estimates are equitable across all three of the services, taking into account the same type of costs, no matter the service background.

Recently, TRAC-White Sands Missile Range (TRAC-WSMR) conducted the Long Range Precision Fires (LRPF) AoA. The objective of LRPF is to mitigate the extended range fires capability gap resulting from the retirement of the Army Tactical Missile System (ATACMS) munitions. Because the ATACMS competes with or compliments other joint fires assets for operational mission demands, TRAC-WSMR evaluated alternatives within a joint context. Evaluation of joint munitions costs (e.g. JADAM, ATACMS, JASSM, etc.) that can meet specific mission demands is relatively straight forward when limited to the cost of the munitions. The main challenge of the project was deriving equitable costs to deliver munitions. In support of the LRPF AoA, TRAC-WSMR cost analysts proposed a methodology that leveraged DoD fixed wing reimbursable rates provided by the OSD Comptroller web page to determine the costs of a sortie and parse the costs to the number of targets attacked plus the cost of munitions used. The Office of the Secretary of Defense – Cost Assessment & Program Evaluation (OSD-CAPE) did not concur with this method as OSD-CAPE did not want this effort and the necessary adjudication across the services to potentially derail the AoA efforts to address the study's main issues. This project is an effort to derive a way to include cross-service cost estimation into TRAC studies with the approval of the other services. As a proof-of-concept, this project will concentrate on equating equitable cross-service costs for fixed-wing munitions delivery platforms. The method of delivery is an essential part of the AoA, especially when the project proposed is the replacement of current missile systems.

The services have historical data for each of the service weapon systems operational costs that can be used as a basis for future cost estimation stored in databases. It is essential to use the correct data from these databases and have a thorough understanding of not only what the costs consists of in the database, but where the data is compiled from.

The DoD reimbursable rates[1] published by the Office of the Secretary of Defense (Comptroller), are not a mandated metric for fixed-wing cost estimation, but a guide that cost estimators can use if they choose. There is no concrete doctrinal cost estimation methodology. Cost estimation is often done using a historical perspective, subject matter expert (SME) elicitation, and institutional knowledge of the systems.

Problem Statement

TRAC-WSMR is unable to equitably supplement operational analysis with the mission costs of meeting specific joint mission demands as desired by study leads and senior decision makers. Determining an acceptable method for calculating mission costs will address this problem. This method should be transferable to other types of platform mission cost estimation, ideally, but the initial proof-of-concept focuses on fixed-wing costs.

The end product of this project will be a method for any service to estimate fixed-wing costs for sorties to use in mission cost estimation for future Analysis of Alternatives (AoAs). If feasible, this method will be adaptable to other systems beside fixed-wing assets.

Issues for Analysis

- What method do the Air Force and Navy use to calculate fixed-wing costs?
- What are the key cost drivers for Air Force and Navy fixed-wing systems?
- What are the costs that should be included in future Analysis of Alternatives documentation when those analysis include fixed-wing assets?
- Where is the costing data stored for historical fixed-wing costs for use in future cost assessments.

Literature Review

There has been a large amount of research into cost estimation for both the Air Force and the Navy costing. The main document that covers the breakdown of the costing metrics for military operations and support is the Operating and Support Cost-Estimating Guide.[2]This guide breaks down the different categories to be used for the services to categorize costing into six different distinct categories. This breakdown is titled the Operations and Support (O&S) Cost Estimating Structure and is depicted in Figure 1.[3]

Aviation operations is a considerable portion of the budget for Air Force and Navy Operations and Maintenance (O&M) budget. The Air Force budged 40% of their 2016 O&M budget

[1] OSD. *Under Secretary of Defene (Comptroller) DoD Reimbursable Rates*. http://comptroller.defense.gov/FinancialManagement/Reports/rates2016.aspx.

[2] Department of Defense. *Operating and Support Cost-Estimating Guide*. DoD, Mar. 2014.

[3] Ibid., p. 6.2.

Second-Level/Third-Level
O&S Cost Estimating Structure

1. Unit-Level Manpower
   - 1.1 Operations
   - 1.2 Unit-Level Maintenance
   - 1.3 Other Unit-Level
2. Unit Operations
   - 2.1 Operating Material
   - 2.2 Support Services
   - 2.3 Temporary Duty
   - 2.4 Transportation
3. Maintenance
   - 3.1 Consumable Materials and Repair Parts
   - 3.2 Depot Level Reparables
   - 3.3 Intermediate Maintenance (External to Unit-Level)
   - 3.4 Depot Maintenance
   - 3.5 Other Maintenance
4. Sustaining Support
   - 4.1 System Specific Training
   - 4.2 Support Equipment Replacement and Repair
   - 4.3 Sustaining/Systems Engineering
   - 4.4 Program Management
   - 4.5 Information Systems
   - 4.6 Data and Technical Publications
   - 4.7 Simulator Operations and Repair
   - 4.8 Other Sustaining Support
5. Continuing System Improvements
   - 5.1 Hardware Modifications
   - 5.2 Software Maintenance
6. Indirect Support
   - 6.1 Installation Support
   - 6.2 Personnel Support
     - 6.2.1 Personnel Administration
     - 6.2.2 Personnel Benefits
     - 6.2.3 Medical Support
   - 6.3 General Training and Education
     - 6.3.1 Recruit & Initial Officer Training
     - 6.3.2 General Skill Training
     - 6.3.3 Professional Military Education

Figure 1. Operating and Support Cost-Estimating Table

towards flight operations, which equates to 14% of their total budget,[4] whereas the Navy budgeted 18% of their 2016 O&M budget, 6% of their total budget to aviation operations.[5] With such a large amount of the respective service budget going to aviation operations, it is important for the services to properly account for fixed wing costs in their yearly budget.

Both the Air Force and the Navy have Flight Hour Programs (FHP) which are in place to estimate the number of flight hours that will be flown for the next year, as this number dictates the amount of funding that each service will receive. This number estimated by each service has been the subject of scrutiny because the forces often request funding for more hours than they can actually fly.[6] Thus, the estimates given by the Air Force and Navy are not always accurate when dealing with flight hours.

Fixed-wing operations costs have been increasing over the years in the Air Force and have remained steady in the Navy. These trends are counter-intuitive, as the Air Force has steadily decreased their number of fixed-wing assets whereas the Navy as increased the number of fixed-wing aircraft. This could be explained by the increase of the cost of some of the more recent procurements for the Air Force, such as the F-35. Figures 2 and 3 show the trends for the Air Force and Navy O&M budgets.

[4] Air Force. *Air Force Financial Management & Comptroller*. http://www.saffm.hq.af.mil/budget/.

[5] Navy. *Department of the Navy Budget Materials*. http://www.secnav.navy.mil/fmc/fmb/Pages/Fiscal-Year-2017.aspx.

[6] Government Accountability Office. *Observations of the Air Force Flying Hour Program*. Tech. rep. GAO, 1999.

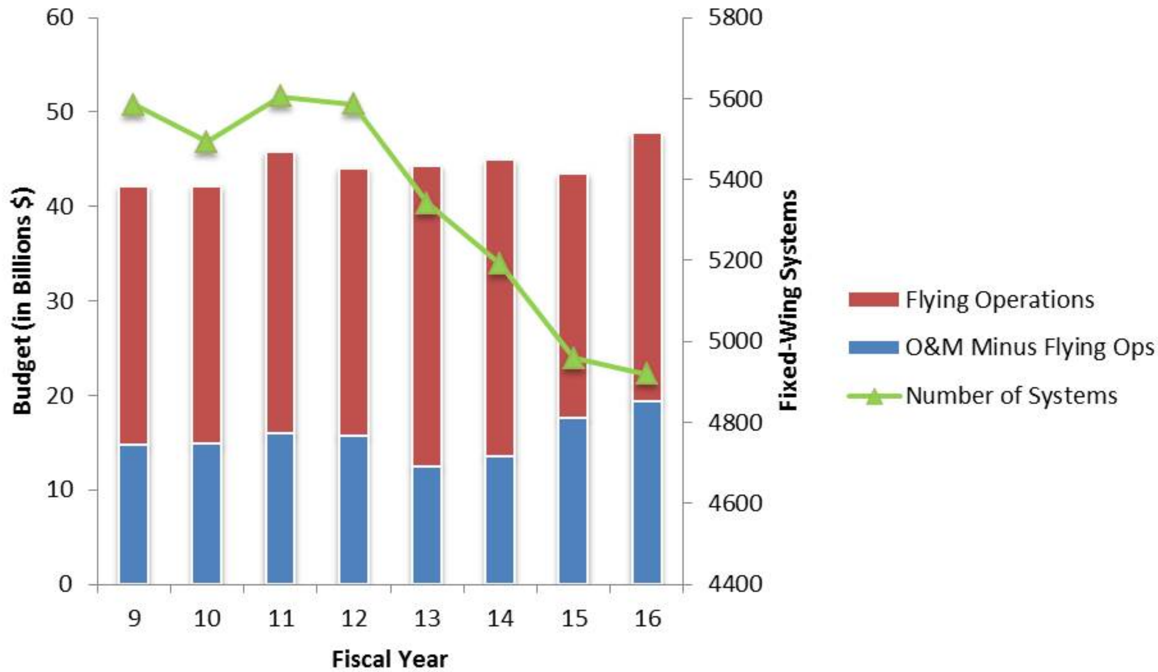

Figure 2. Air Force O&M Budget by Fiscal Year

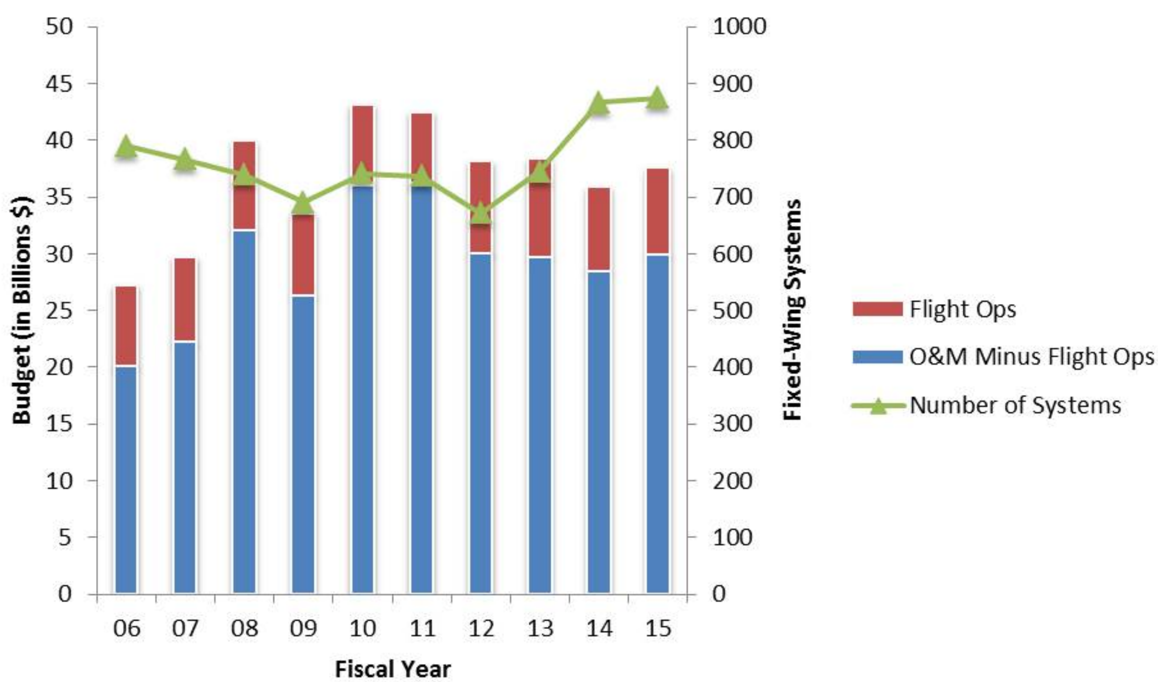

Figure 3. Navy O&M Budget by Fiscal Year

In his Master's thesis, Tyler J. Hess wrote about cost forcasting models for the Air Force Flying Hour program.[7] Hess evaluated the current methods used by the Air Force for establishing the budget for the Air Force Flying Hour Program (FHP) and proposed new methods of cost estimation. Hess's method concentrated on the age of the aircraft, the number of landings, and the number of sorties that the craft was involved in over a fiscal year. He used these variables because of the high positive correlation between sorties, landings, and net costs and the negative correlation between age and net costs.

A Rand Technical Report titled "Cost Adjustment Sheets and the Flying Hour Program" delved into the details of the Naval (FHP).[8] The report focused on the Cost Adjustment Sheets (CASs) and the role that CASs play in the Navy's FHP. The report also assessed the increase in the cost per flight hour for one of the Navy's most prevalent fighter systems, the F/A-18. The cost per flying hour increased between 2003 from $2,803 and hour to $4252[9] an hour in 2004. The cost per flight hour in 2014, the latest year we have supporting data for and using the same metrics that were used in the report for the F/A-18 in 2016 dollars, is around $7300. This accentuates the fact that there is an increase in the cost per flight hour over the years for at least one type of system, even with the stationary nature of the O&M budget for the Navy.

A 2015 report by a team from RAND set out with the mission of developing a consistent and equitable means of comparing aircraft mission costs between different aircraft.[10] The report goes into detail about the different methods of equating CPFH for different types of analysis. The researchers came to the conclusions that the best method to equate CPFH for multiple different aircraft is to normalize as many of the costs as possible and use O&S Categories 1.0 through 5.0, leaving out category 6.0 because of the inconsistencies of reporting indirect support across different systems. The report also recommends different methods of costing aircraft, such as cost per system or cost per Air Force unit.

There are differing opinions on how costs should be determined for aircraft. A 2010 report out of the Logistics Management Institute took the approach of evaluating the number of sorties and landings that the aircraft experienced, as opposed to the number of flight hours to calculate costs.[11] The authors claim that their method is more robust, especially during surges in aircraft use.

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Project Team

Constraints, Limitation, and Assumptions

Constraints limit the study team's options to conduct the study. *Limitations* are a study team's inabilities to investigate issues within the sponsor's bounds. *Assumptions* are study-specific statements that are taken as true in the absence of facts.

- Constraints
  - Complete the project by 30 September 2016.
- Limitations
  - The analysis must work off of previous historical fixed-wing costing databases; no new research.
- Assumptions
  - The AoAs used for the research have valid costing data.
  - The finance data from VAMOSC and AFTOC is valid.

Methodology

The execution of this project will follow the technical approach outlined in this section. First the team will review the relevant literature and identify the appropriate analysis techniques fixed-wing related data. Second, the team will explore other techniques for cost estimation of fixed-wing systems in an attempt to find the best current methods of fixed-wing cost per flying hour. During this phase, the team will attempt to root out any differences in the costing between the Air Force and the Navy. In the final phase, we will condense all of our research into a tech report for presentation to the project sponsor. We show the methodology in Figure 4.

[7] Tyler J. Hess. "Cost Forcasting Models for the Air Force Flying Hour Program". MA thesis. Air Force Institiue of Technology, Mar. 2009.

[8] Edward G. Keating, Sarah H. Bana, and Michael Boito. *Naval Aviation BudBudget: Cost Adjustment Sheets and the Flying Hour Program.* Tech. rep. RAND National Defense Research Institute, 2012.

[9] Original costs in the document were given in FY10 dollars and were inflated to FY16 dollars amounts

[10] Edward G. Keating et al. *Metrics to Compare Aircraft Operating and Support Costs in the Department of Defense.* Tech. rep. RAND, 2015.

[11] John M. Wallace, Schot A. Houser, and David A. Lee. *A Physics-Based Alternative to Cost-Per-Flying-Hour Models of Aircraft Consumption Costs.* Tech. rep. Logistics Management Institute, 2010.

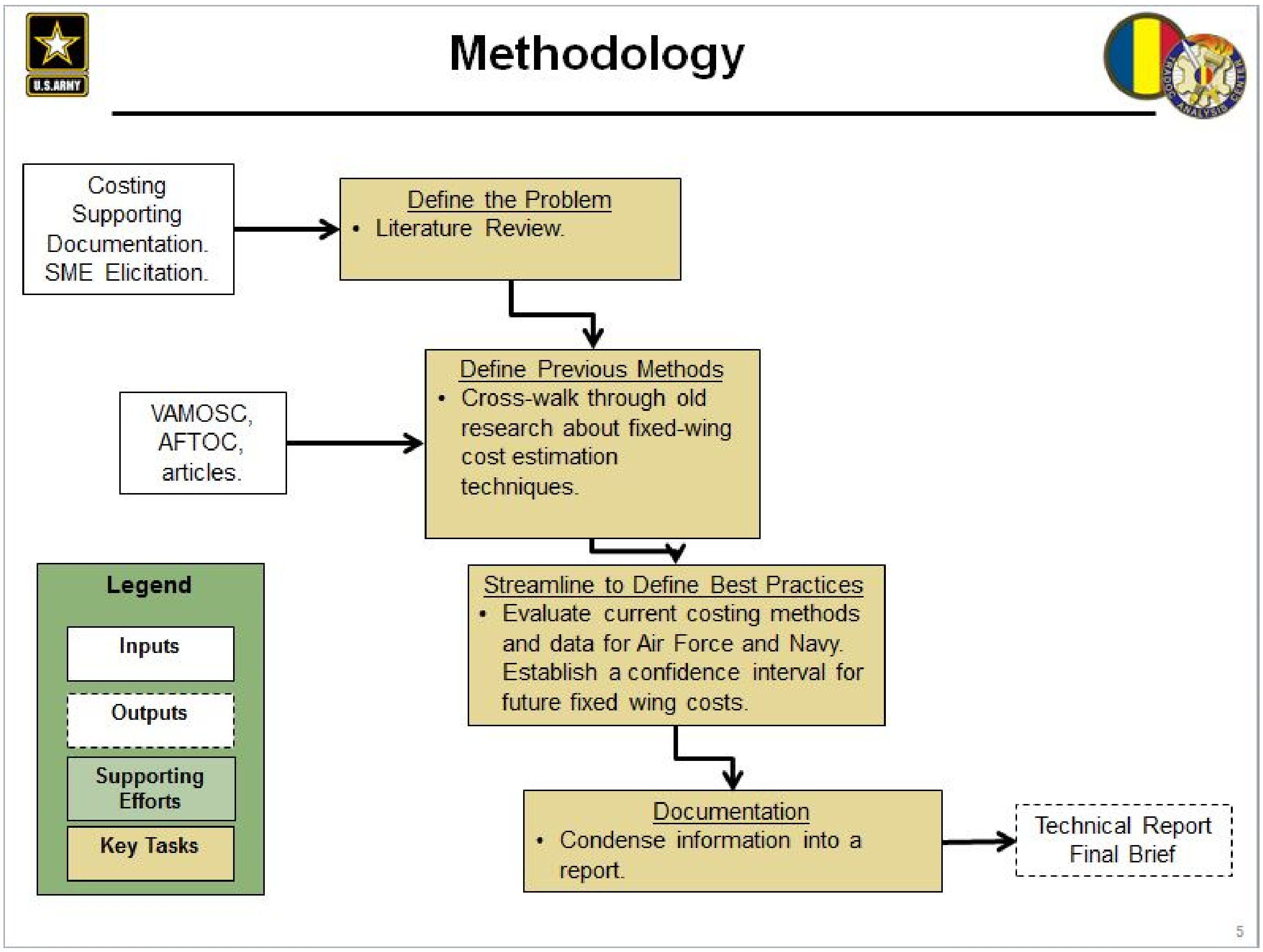

Figure 4. Methodology

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Chapter 2
Methodology

Data Collection

All of the data used in this study was taken from two different databases: the Air Force Total Ownership Cost (AFTOC)[12] for the Air Force historic data and Visibility and Management of Operating and Support Costs (VAMOSC)[13] for the Navy. Both of these databases store their data according to the Operating and Support Cost-Estimating Guide, with the exception that VAMOSC does not collect catagory 6.0: Indirect Support. Examples of the data taken from AFTOC and VAMOSC are located in Appendix A. The data was downloaded to Microsoft Excel for aggregation and manipulation.

Analysis of the Data

The range of the data downloaded was from FY 1997 to FY 2015. To eliminate a discrepancy due to the inflation, all of the data was downloaded with a baseline of FY 2016 dollars. Only systems that had complete data from FY 1997 to FY 2015 were used in this analysis, limiting the amount of fixed wing systems that could be evaluated. The exception is the Air Force F-22, which has only been in service since 2005.

Cost Per Flight Hour

Both the Navy and the Air Force us the Cost Per Flight Hour (CPFH) as the main metric for calculating budgeting for fixed-wing assets. CPFH can take different categories of the O&S Cost Estimating Structure into account. For instance, life cycle cost estimates may need to take into account the total ownership cost using all six of the categories in the O&S Cost Estimate Structure. Whereas, logistic agencies may take a smaller subset of the O&S Cost Estimate Structure into account for CPFH, leaving out most of 1.0 Unit-Level Manpower and categories 5.0 and 6.0.

There are many different methods of deriving the CPFH for a system. Different departments within DoD are concerned with different types of costs and may require a different calculation for CPFH. Figure 5 gives a range of the different types of CPFH calculations and the O&S categories for each of those calculations.

[12] Air Force. *Air Force Total Ownership Cost (AFTOC)*. https://aftoc.hill.af.mil/.
[13] Navy. *Navy Visisitilby and Management Of Operating and Support Costs (VAMOSC)*. https://www.vamosc.navy.mil/.

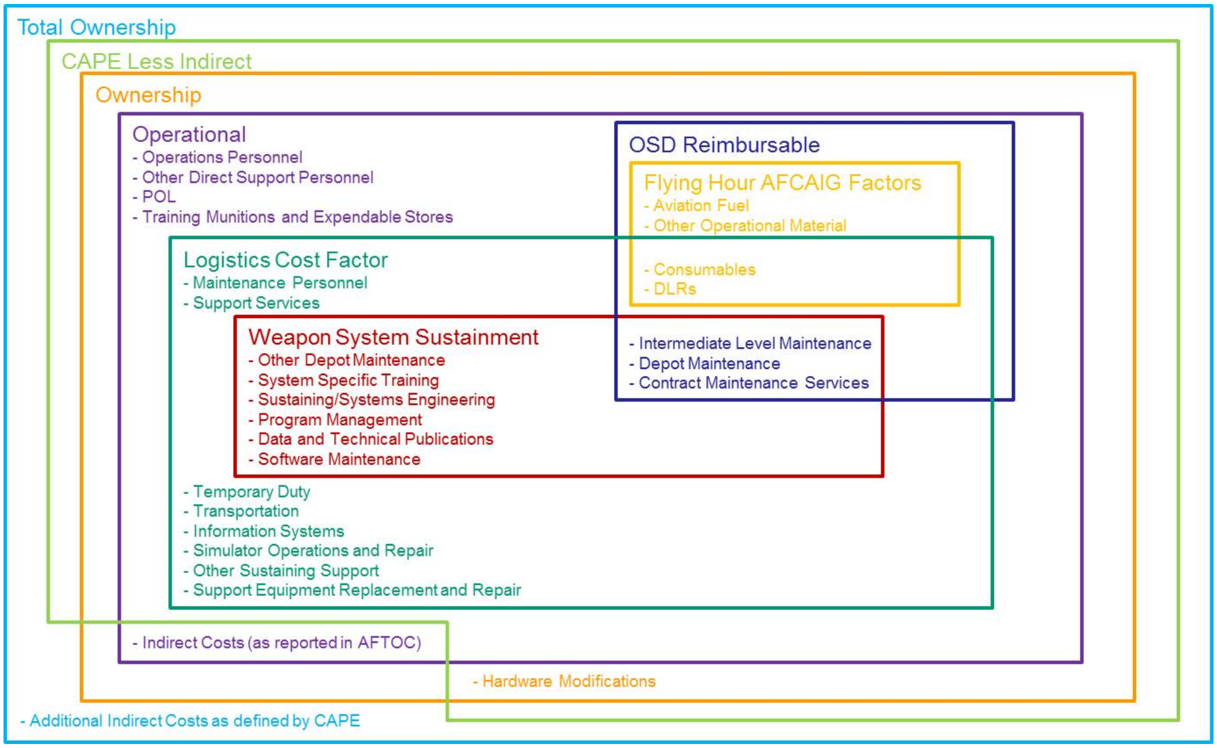

Figure 5. Different CPFH Metrics used in DoD

Department of Defense Fixed-Wing Reimbursable Rates CPFH

The Under Secretary of Defense (Comptroller) publishes a yearly document detailing the reimbursable rates for fixed-wing assets in all of the services.[14] This rate covers parts of both 2.0 Unit Operations and 3.0 Maintenance categories. This measure is detailed in the Department of Defense Financial Management Regulation (DoD 7000.14-R), Volume 11A: "Reimbursable Operations, Policy," Chapter 6, Appendix G. This regulation states that the "DoD rate will include costs for ... Fuel, ...[Depot Level Repairables], ...Depot Mainenance, and ... Other."[15] The "other" category consists of Contract Level Support (CLS) or any other consumables annotated in the OP-20 guidance for the corresponding service. Any requester outside of DoD will also incur the added cost of the personnel to operate the fixed-wing assets which will be computed using the cost for the authorized crew taken from the OSD reimbursable rates for military personnel, another document published by the Undersecretary of Defense (Comptroller). The O&S categories used in the reimbursable rates calculation are listed in Table 1.

CAPE Less Indirects

A more comprehensive view of the cost to operate a fixed-wing asset is attained by using the CAPE less Indirects cost for CPFH. This cost would include categories one through five

[14] OSD, *Under Secretary of Defene (Comptroller) DoD Reimbursable Rates*, op. cit.

[15] *Department of Defense Financial Management Regulation (DoD FMR)*. Department of Defense.

Table 1. Reimbursable Rate Categories

1.0	**UNIT-LEVEL MANPOWER**
1.1	Operations Personnel
1.2	Maintenance Personnel
1.3	Other Direct Support Personnel
2.0	**UNIT OPERATIONS**
2.1	Operating Material
2.1.1	Maintenance Personnel
2.1.1.1	Aviation Fuel
2.1.1.2	POL
2.1.2	Training Munitions and Expendables
2.1.3	Other Operational Material
2.2	Support Services
2.3	Temporary Duty
2.4	Transportation
3.0	**MAINTENANCE**
3.1	Consumable Materials and Repair Parts
3.2	Depot Level Repairs (DLRs)
3.3	Intermediate Maintenance
3.4	Depot Maintenance
3.5	Other Maintenance
3.5.1	Contract Maintenance Services
3.5.2	Other Depot Maintenance
4.0	**SUSTAINING SUPPORT**
4.1	System Specific Training
4.2	Support Equipment Replacement and Repair
4.3	Sustaining/Systems Engineering
4.4	Program Management
4.5	Information Systems
4.6	Data and Technical Publications
4.7	Simulator Operations and Repair
4.8	Other Sustaining Support
5.0	**CONTINUING SYSTEM IMPROVEMENTS**
5.1	Hardware Modifications
5.2	Software Modification
6.0	**INDIRECT SUPPORT**

of the O&S Cost Estimation Guide categories, leaving out category 6.0 Indirect Support. The reason to leave out Indirect Support is that the different services often have differing methodologies for capturing the Indirect Costs for their systems. All five of the other categories are fairly equitable across the varying services. The only difference found during this research was some of the naming conventions of the sub-categories vary between the Air Force and the Navy, but the root categories are identical between those two services. The categories used to compute the CPFH using Cape less Indirects are enumerated in Table 2.

Key Cost Drivers for Fixed-Wing Assets

Using the data from the systems, we were able to evaluate the main causes drivers of expense for fixed-wing assets. The conclusions are that depot level maintenance and personnel

Table 2. CAPE Less Indirect Categories

1.0	**UNIT-LEVEL MANPOWER**
1.1	Operations Personnel
1.2	Maintenance Personnel
1.3	Other Direct Support Personnel
2.0	**UNIT OPERATIONS**
2.1	Operating Material
2.1.1	Maintenance Personnel
2.1.1.1	Aviation Fuel
2.1.1.2	POL
2.1.2	Training Munitions and Expendables
2.1.3	Other Operational Material
2.2	Support Services
2.3	Temporary Duty
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4.4	Program Management
4.5	Information Systems
4.6	Data and Technical Publications
4.7	Simulator Operations and Repair
4.8	Other Sustaining Support
5.0	**CONTINUING SYSTEM IMPROVEMENTS**
5.1	Hardware Modifications
5.2	Software Modification
6.0	**INDIRECT SUPPORT**

represented by O&S categories 1.0 and 3.0, are the categories that drive up the cost per flight hour. Figures 6 and 7 show two different cost diagrams, one for an Air Force A-10 and one for a Navy A-6, two comparable systems. The two images depict what was found during this research, with categories 1.0 and 3.0 making up the majority of fixed-wing costs, with occasional spikes in some of the other fields like 5.0 Continuing System Improvements. Category 6.0 Indirect Support was left off of the graphs as this category makes up a very small portion of the overall cost and is not supplied in the Navy VAMOSC system.

Prediction of Future CPFH

There is a generally upward trend for the CPFH per systems in both the Air Force and the Navy. We used three different examples to show the trends for fixed-wing costs FY 1997 to

FY 2015.

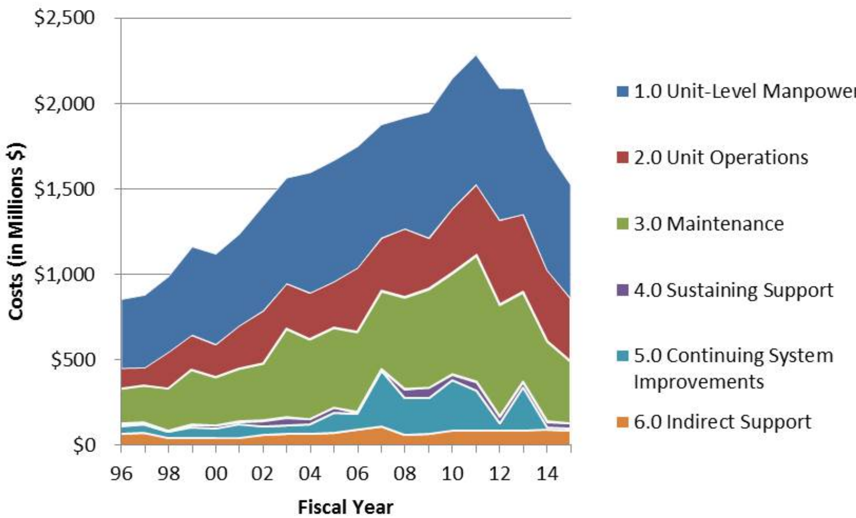

Figure 6. Air Force A-10 Costs by Fiscal Year

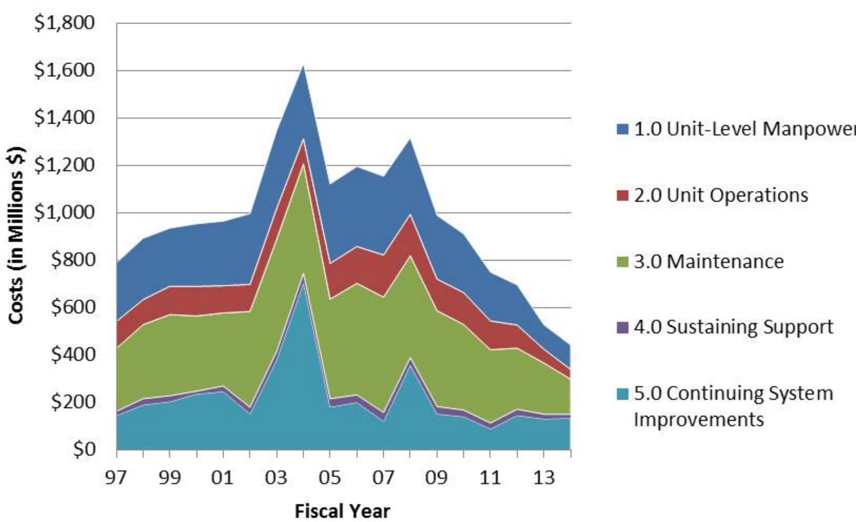

Figure 7. Navy A-6 Costs by Fiscal Year

To predict future CPFH for fixed-wing systems, we equated a linear regression function. To begin with, we calculate each systems CPFH using Equation 1. This number served as our independent variable. There were such large discrepancies between the low CPFH values and the high CPFH values that we transformed this value using the natural log function.

$$\frac{\sum(\text{O\&S Categories 1.0 through 5.0})}{\text{Total Flight Hours}} \tag{1}$$

Our independent variables for the linear regression were fiscal year and mission design (MD). MD is the name given to the overarching category of aircraft, with mission design series (MDS) designating the subcategory. For instance, an MD may be the F-22, with an MDS being F-22A. The final linear equation is expressed by Equation 2.

$$\begin{gathered}\ln\left(\mathrm{CPFH}_{MD}\right) = \alpha(\text{Fiscal Year}) + \beta(\text{MD}) \\ \text{where } \alpha \text{ and } \beta \text{ are the coefficients for each variable.}\end{gathered} \tag{2}$$

We used the resulting coefficient for the Fiscal Year variable to calculate a percentage increase per fiscal year for the CPFH per year.

In addition to the predicted increase per year of CPFH, we also calculated a 95% confidence interval around the mean CPFH for all of the systems. This gave us an indication of the boundaries on the CPFH for fixed-wing systems.

Chapter 3
Results

Example Using Various Systems

This example uses the systems listed in Table 3. The resulting trend lines over the fiscal years are shown in Figure 8.

Table 3. Systems Evaluated

Air Force	Navy
A-10	A-6
B-2	C-130
C-130	E-2
F-15	E-6
F-16	F-5
	F/A-18

The regression function for this data is expressed in Equation 3. The only part of this equation that we will use for the prediction of fixed wing costs is the coefficient for fiscal year. The R squared for this equation is 0.95 and all of the p-values for the coefficients are far below 0.05, with the exception of the p-value for the F-16, which was 0.42. This large p-value is inconsequential as we are using the regression function to find the increase in CPFH, regardless of MD.

$$\begin{aligned}
&\ln(\text{CPFH}) = -85.95 + 0.048(\text{Fiscal Year}) \\
&+ 0.66(\text{A-6}) + 1.99(\text{B-2}) - \\
&0.16(\text{C-130}) + 0.39(\text{E-2}) + \\
&0.48(\text{E-6}) + 0.52(\text{F-15}) + \\
&0.04(\text{F-16}) - 0.55(\text{F-5}) + \\
&0.11(\text{F/A-18})
\end{aligned} \tag{3}$$

This coefficient is 0.048, however, this is the natural log of the coefficient and thus must be exponentiated, giving a total coefficient of 1.048. This means that we should increase the cost of fixed wing assets by 4.8% from the previous year's estimate.

We also computed a 95% confidence interval on the mean CPFH from the given systems. This confidence interval is for the mean CPFH of 28413.44 is (24039.40 32787.48). This is a large confidence interval, but this is most likely because of the addition of the B-2 Bomber,

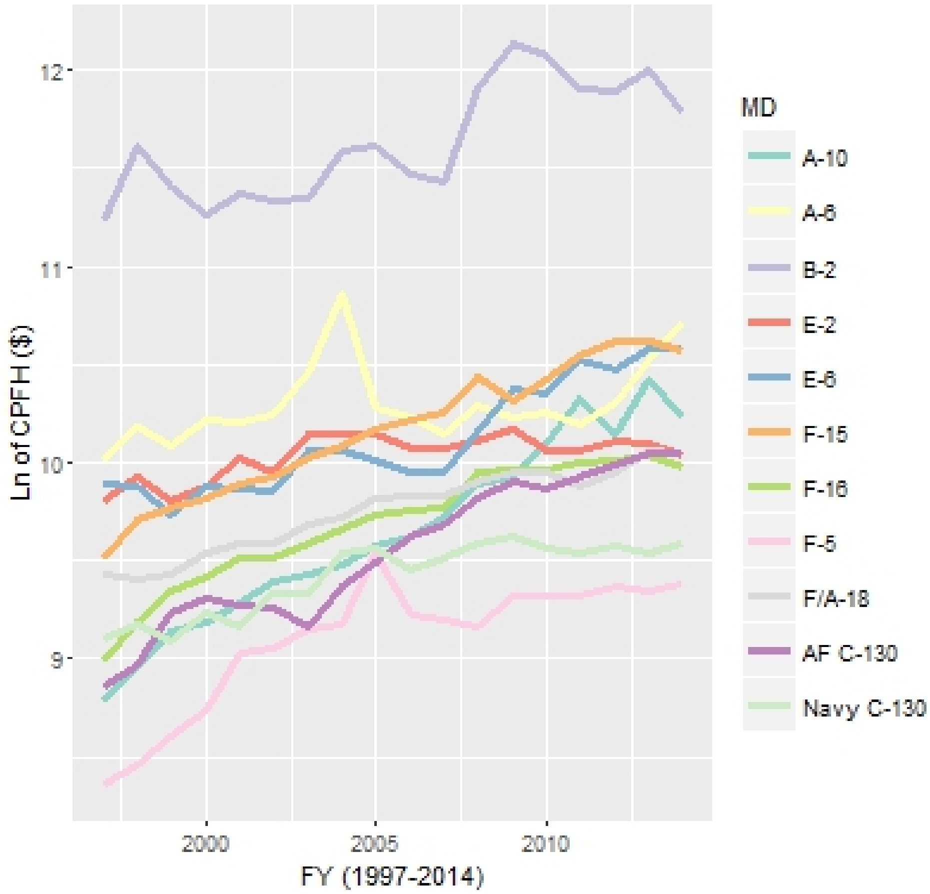

Figure 8. CPFH Trends of Various Aircraft

a very expensive CPFH system.

Example Using Only Fighter Systems

It is very likely that an AoA will need an estimate of the CPFH for fighter jet delivery platforms and thus the analysis was performed using only fighters with the MDs listed in Table 4.

Table 4. Fighter MDs Evaluated

Air Force	Navy
A-10	A-6
F-15	AV-8
F-16	F/A-18
	F-5

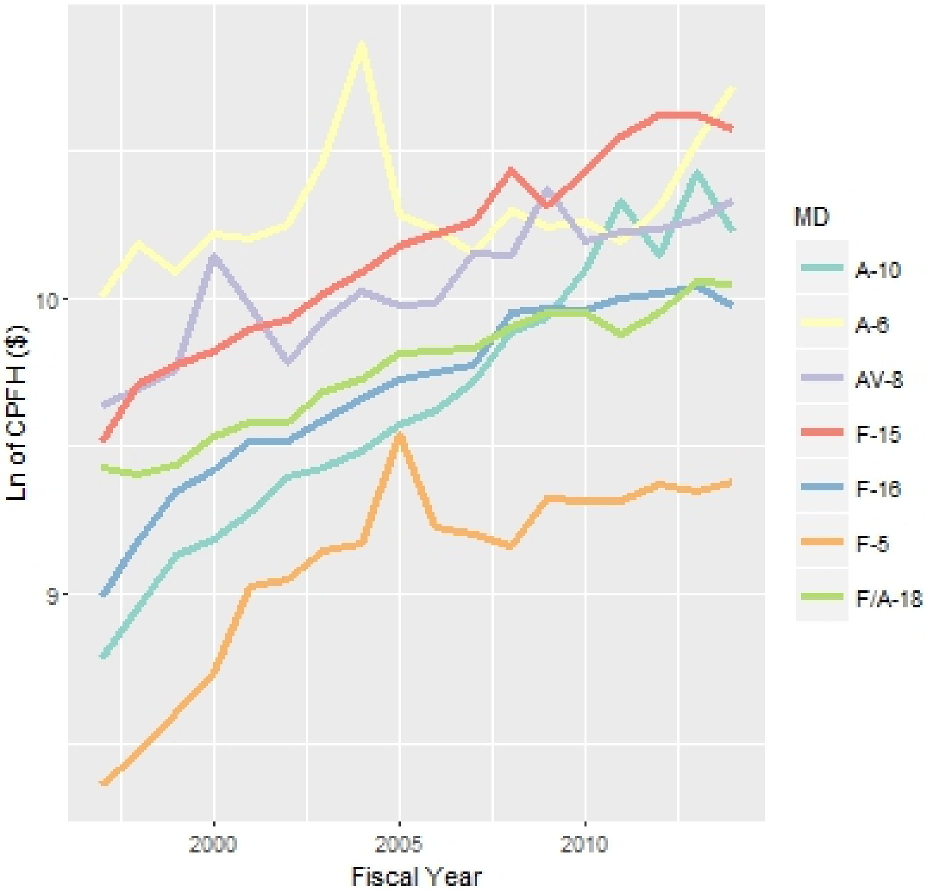

Figure 9. CPFH Fighter Trends

$$\begin{aligned}
&\ln(\text{CPFH}) = -91.46 + 0.05(\text{Fiscal Year}) \\
&+ 0.66(\text{A-6}) + 0.40(\text{AV-8}) + \\
&0.52(\text{F-15}) + 0.04(\text{F-16}) - \\
&0.55(\text{F-5}) + 0.11(\text{F/A-18})
\end{aligned} \tag{4}$$

This coefficient is 0.05, giving a coefficient of 1.052 after exponentiation. Thus, when only taking into account fighter systems, the CPFH should increase by 5.2% from the previous year's estimate.

We also computed a 95% confidence interval on the mean CPFH for the fighter systems. This confidence interval is for the mean CPFH of 20349.13 is (18755.06, 21943.19).

Example With the Inclusion of the F-22

The Air Force F-22 is a system of particular interest to the sponsor. The study team conducted the analysis including the F-22. Unfortunately, the F-22 has only been in the Air Force inventory since 2005 and thus we had to restrict our analysis to data from FY 2006 to FY 2014 using the systems found in Table 5.

Table 5. Fighters Evaluated with the F22 Included

Air Force	Navy
A-10	A-6
F-15	AV-8
F-16	F/A-18
F-22	F-5

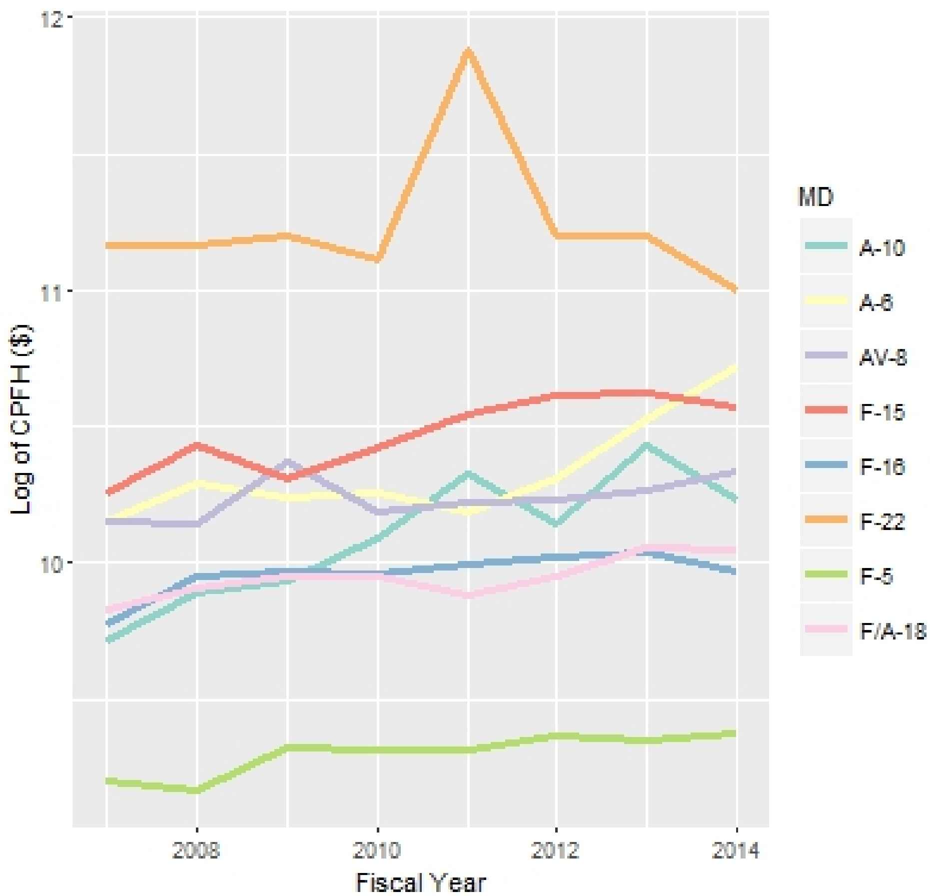

Figure 10. CPFH Fighter Trends with the F22 Included

$$
\begin{aligned}
\ln(\text{CPFH}) = -65.19 + 0.04(\text{Fiscal Year}) + \\
0.28(\text{A-6}) + 0.17(\text{AV-8}) + \\
0.40(\text{F-15}) - 0.10(\text{F-16}) + \\
1.20(\text{F-22}) - 0.75(\text{F-5}) - \\
0.11(\text{F/A-18})
\end{aligned}
\tag{5}
$$

This coefficient for Fiscal Year in this equation is 0.04, giving a coefficient of 1.038 after exponentiation. Thus, when only taking into account fighter systems, the CPFH should increase by 3.8% from the previous year's estimate.

We also computed a 95% confidence interval on the mean CPFH for the fighter systems with the inclusion of the F-22. This confidence interval is for the mean CPFH of 31028 is (25942.69, 36113.31).

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Chapter 4
Summary and Conclusions

- What method do the Air Force and Navy use to calculate fixed-wing costs?

  There are various types of CPFH that the Air Force and the Navy will use, but both services use the same metrics for estimating those costs, namely the O&S Cost Structure categories. Neither service seems to use the sixth category: 6.0 Indirect Support for calculations, being that indirect support is not a category that is dutifully recorded and consistent across the services. Both the Navy and the Air Force compute their service respective fixed-wing reimbursable rates reported to the OSD Comptroller in the same manner, regulated by the FMR guidance.[16]

- What are the key cost drivers for Air Force and Navy fixed-wing systems?

  Although all of the costs associated with fixed-wing operation are in the millions of dollars yearly, the main drivers of the high cost of fixed-wing operations are categories 1.0 Unit-Level Manpower and 3.0 Maintenance. Aviation fuel falls under 2.0 Unit Operations and is often a large cost in the fixed-wing operation, but can fluctuate greatly with the cost of fuel, whereas the cost of unit-level manpower and maintenance are fairly fixed and are always a large portion of the budget for DoD aircraft.

- What are the costs that should be included in future Analysis of Alternatives documentation when those analysis include fixed-wing assets?

  It is the recommendation of this research to include the first five categories for the O&S Costing Guidance in future AoAs. These five categories are all reported in the respective services' costing databases and do not contain the ambiguity that is inherit in indirect support.

- Where is the costing data stored for historical fixed-wing costs for use in future cost assessments.

  All costing data needed for future research is located in the AFTOC and VAMOSC repositories. These databases have restricted access, but access can be obtained within a few working days, thus making the information readily available to all DoD personnel. Should the need arise, similar data can be obtained for the Army via the Operating and Support Management Information System (OSMIS) database, the Army's version

[16] Ibid.

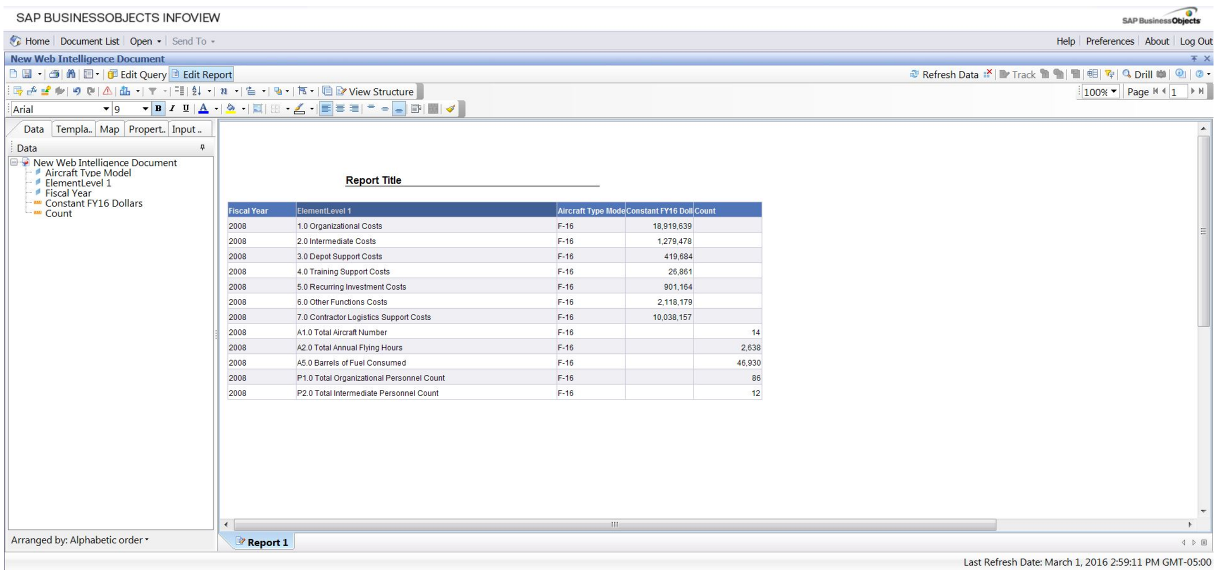
of VAMOSC.

The cost per flight hour for fixed-wing systems is used as a metric for budgeting in all of the branches of the service. Different aspects of the O&S Cost Estimation Categories will be taken into account for different types of budgeting within the calculation of the CPFH. The DoD Fixed-Wing Reimbursable rates posted on the OSD Comptroller web page covers only a few of the different possible O&S Cost Estimation Categories, mainly concentrating on repair parts and fuel use. For use in a cross service cost estimation, it is recommended to use a more inclusive method of CPFH estimation, such as using the CAPE costs minus Indirect costs, which consists of categories one through five of the O&S Cost Estimation Categories. This method only leaves out category 6.0 Indirect Costs, a field that can differentiate widely between services and is not a key cost driver when evaluated with the Air Force Systems.

The main cost drivers for fixed-wing costs are categories one through three which consist of the personnel and maintenance of the system. Other variables can also effect the CPFH, such as the number of systems owned by the service and the age of the system, but these measures should be carefully scrutinized if they are to be a factor in CPFH as they can sometimes be unintuitive; for example: high CPFH of the B-2 with the small amount (usually around 20) of B-2s in the Air Force Inventory.

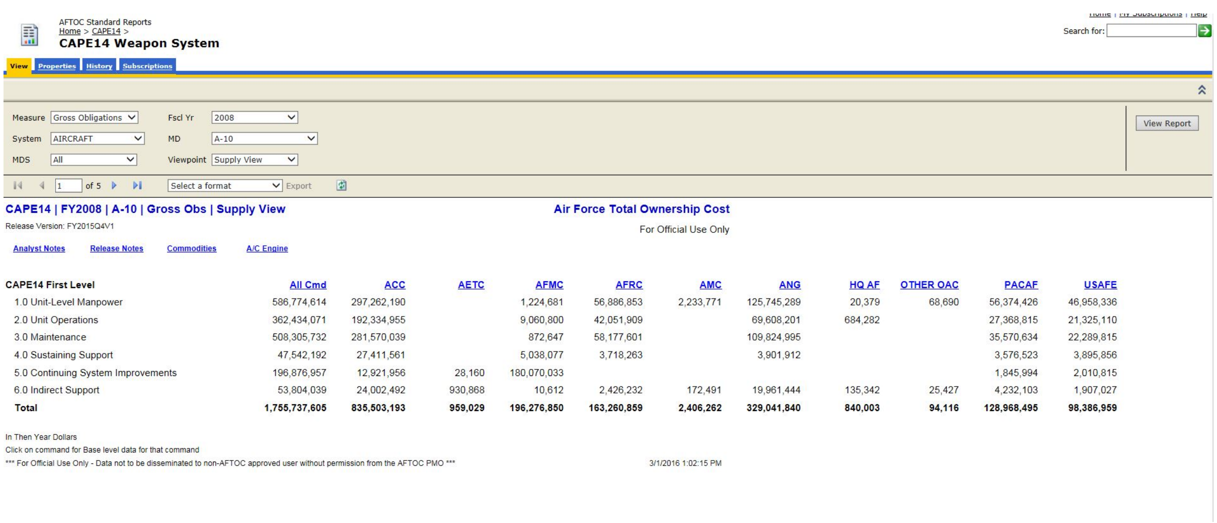
Future analysis should use historic costing records taken from the services respective databases (AFTOC for Air Force and VAMOSC for Navy) to compute an estimate for to be included in future research. A regression model can help assist an analyst in creating an estimated CPFH based on the average CPFH of a given Fiscal Year. The regression model can be reequated using the most important aircraft for a specific AoA, such as using only fighters for a missile based AoA or only cargo craft for a cargo based AoA.

Appendix A
Data Examples



Fiscal Year	ElementLevel 1	Aircraft Type Mode	Constant FY16 Doll	Count
2008	1.0 Organizational Costs	F-16	18,919,639	
2008	2.0 Intermediate Costs	F-16	1,279,478	
2008	3.0 Depot Support Costs	F-16	419,684	
2008	4.0 Training Support Costs	F-16	26,861	
2008	5.0 Recurring Investment Costs	F-16	901,164	
2008	6.0 Other Functions Costs	F-16	2,118,179	
2008	7.0 Contractor Logistics Support Costs	F-16	10,038,157	
2008	A1.0 Total Aircraft Number	F-16		14
2008	A2.0 Total Annual Flying Hours	F-16		2,638
2008	A5.0 Barrels of Fuel Consumed	F-16		46,930
2008	P1.0 Total Organizational Personnel Count	F-16		86
2008	P2.0 Total Intermediate Personnel Count	F-16		12

Figure A–1. Example of Data Collected from VAMOSC



CAPE14 First Level	All Cmd	ACC	AETC	AFMC	AFRC	AMC	ANG	HQ AF	OTHER OAC	PACAF	USAFE
1.0 Unit-Level Manpower	586,774,614	297,262,190		1,224,681	56,886,853	2,233,771	125,745,289	20,379	68,690	56,374,426	46,958,336
2.0 Unit Operations	362,434,071	192,334,955		9,060,800	42,051,909		69,608,201	684,282		27,368,815	21,325,110
3.0 Maintenance	508,305,732	281,570,039		872,647	58,177,601		109,824,995			35,570,634	22,289,815
4.0 Sustaining Support	47,542,192	27,411,561		5,038,077	3,718,263		3,901,912			3,576,523	3,895,856
5.0 Continuing System Improvements	196,876,957	12,921,956	28,160	180,070,033						1,845,994	2,010,815
6.0 Indirect Support	53,804,039	24,002,492	930,868	10,612	2,426,232	172,491	19,961,444	135,342	25,427	4,232,103	1,907,027
Total	**1,755,737,605**	**835,503,193**	**959,029**	**196,276,850**	**163,260,859**	**2,406,262**	**329,041,840**	**840,003**	**94,116**	**128,968,495**	**98,386,959**

In Then Year Dollars
Click on command for Base level data for that command
*** For Official Use Only - Data not to be disseminated to non-AFTOC approved user without permission from the AFTOC PMO ***
3/1/2016 1:02:15 PM

Figure A–2. Example of Date Collected from AFTOC

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Appendix B
References

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[2] Navy. *Navy Visisitilby and Management Of Operating and Support Costs (VAMOSC)*. https://www.vamosc.navy.mil/.

[3] Department of Defense. *Operating and Support Cost-Estimating Guide*. DoD, Mar. 2014.

[4] OSD. *Under Secretary of Defene (Comptroller) DoD Reimbursable Rates*. http://comptroller.defense.gov/FinancialManagement/Reports/rates2016.aspx.

[5] Air Force. *Air Force Financial Management & Comptroller*. http://www.saffm.hq.af.mil/budget/.

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[10] Edward G. Keating et al. *Metrics to Compare Aircraft Operating and Support Costs in the Department of Defense*. Tech. rep. RAND, 2015.

[11] John M. Wallace, Schot A. Houser, and David A. Lee. *A Physics-Based Alternative to Cost-Per-Flying-Hour Models of Aircraft Consumption Costs*. Tech. rep. Logistics Management Institute, 2010.

[12] *Department of Defense Financial Management Regulation (DoD FMR)*. Department of Defense.

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Appendix C
Glossary

AFCAA	Air Force Cost Analysis Agency
AFTOC	Air Force Total Ownership Cost
ATACMS	Army Tactical Missile System
AoA	Analysis of Alternatives
CAPE	Cost Assessment and Program Evaluation
CPFH	Cost Per Flying Hour
DLR	Depot-Level Reparable
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities
FH	Flying Hours
FHP	Flying-Hour Program
FY	Fiscal Year
GAO	Government Accountability Office
LRPF	Long Range Precision Fires
MD	Mission Design
MDS	Mission Design Series
O&M	Operating and Maintenance
O&S	Operating and Support
OSD	Office of the Secretary of Defense
PAI	Primary Aircraft Inventory
POL	Petroleum, Lubricants, and Oil
SME	Subject Matter Expert
TAI	Total Active Inventory
TRAC	Training and Doctrine Command Analysis Center
TRADOC	U.S. Army Training and Doctrine Command
WSMR	White Sands Missile Range
VAMOSC	Visibility and Management of Operation and Support Costs

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Appendix D
Points of Contact

Below is a listing of the points-of-contact from the different agencies that I worked with on this project:

Name	Department	Phone Number	Email
Russell, Sara	OUSD Comptroller	703-614-7941	sara.l.russell.civ@mail.mil
Wells, Duke K.	Navy Air	301-342-0186	kenneth.d.wells@navy.mil
Mushrush, Jason	Navy Air	301-757-2429	jason.mushrush@navy.mil
Mably, Lisa	AFCAA	240-612-5544	lisa.a.mably.civ@mail.mil
Turner, Scott	AFCAA	240-612-5539	manson.s.turner.civ@mail.mil

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Appendix E
R Code

```
setwd("~/Cost Estimation/R Working Folder")


library(RColorBrewer)

fighter<-read.csv("Fighter Data.csv", header=T)
ce<-read.csv("CEWorkingDoc.csv", header=T)
afc130<-which(ce$MD=="C-130"&ce$Force=="Air Force")
nc130<-which(ce$MD=="C-130"&ce$Force=="Navy")
levels(ce$MD)<-c(levels(ce$MD), "AF C-130", "Navy C-130")

ce$MD[afc130]<-"AF C-130"
ce$MD[nc130]<-"Navy C-130"

systems<-c("A-10","A-6","B-2", "AF C-130","Navy C-130", "E-2","E-6","F-16","F-5", "F/A-1
ce1<-ce[ce$MD%in%systems,]
ce1<-ce1[ce1$FY>1996&ce1$FY<2015,]

a<-ggplot(data=ce1, aes(x=FY, y=log(CPFH), group=MD))+geom_line(aes(color=MD), size=1.2)
a<-a+scale_colour_brewer(palette="Set3")
a<-a+labs(title="CPFH Trends over the Fiscal Years", x="FY (1997-2014)", y="Ln of CPFH (
a


lm1<-lm (log (CPFH) ~ FY + MD, data = ce1)

##I need to know the FY coefficient
exp(lm1$coefficients[[2]])

###What about a confidence inteval for the most optimal CPFH circa FY 2016
t.test(ce1$CPFH)



###This is the CPFH trends for Fighter Jets graphic.
systems<-c("A-10","A-6","AV-8","F-5", "F/A-18","F-15", "F-16")
ce1<-ce[ce$MD%in%systems,]
```

```
ce1<-ce1[ce1$FY>1996&ce1$FY<2015,]

#Lay the groundwork for the plot. We are only going to use the years 1997 to 2014.

a<-ggplot(data=ce1, aes(x=FY, y=log(CPFH), group=MD))+geom_line(aes(color=MD), size=1.2)
a<-a+scale_colour_brewer(palette="Set3")
a<-a+labs(title="CPFH Trends for Fighter Jets", x="Fiscal Year", y="Ln of CPFH ($)")
a

##For the linear regression
lm1<-lm (log (CPFH) ~ FY + MD, data = ce1)

##I need to know the FY coefficient
exp(lm1$coefficients[[2]])

###What about a confidence inteval for the most optimal CPFH circa FY 2016
t.test(ce1$CPFH)


##I need the FIGHTER data set with F22s for the first picture:
systems<-c("A-10","A-6","AV-8","F-5", "F/A-18","F-15", "F-16", "F-22")
fighter22<-ce[ce$MD%in%systems,]
fighter22<-fighter22[fighter22$FY>2006&fighter22$FY<2015,]


a<-ggplot(data=fighter22, aes(x=FY, y=log(CPFH), group=MD))+geom_line(aes(color=MD), siz
a<-a+scale_colour_brewer(palette="Dark2")
a<-a+labs(title="CPFH Trends with F-22 Included", x="Fiscal Year", y="Log of CPFH ($)")
a

###Now to run some regressions for this data: We are only going to do FY
###versus MD to predict the log of CPFH.
###This is pretty much garbage for actual predictions, but pretty good to show a trend.

lm1<-lm (log (CPFH) ~ FY + MD, data = fighterw22)

##I need to know the FY coefficient
exp(lm1$coefficients[[2]])

###What about a confidence inteval for the most optimal CPFH circa FY 2016
t.test(fighterw22$CPFH)
```